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Solar-Like Oscillations in β Hydri: Evidence for Short-Lived High-Amplitude Oscillations

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Abstract. Velocity measurements of the G2 subgiant β Hyi with both UCLES and CORALIE show a clear excess of power centred at 1.0 mHz. In the UCLES data we find evidence for a short-lived, high-amplitude oscillation event. If confirmed as a feature of subgiants, such 'starquakes' would make it harder to measure accurate mode frequencies and perform asteroseismology.

1. Introduction

As reported by Bedding et al. (2001) and Carrier et al. (2001), we have made a clear detection of excess power from Doppler observations of the G2 subgiant β Hyi. We observed this star with the UCLES echelle spectrograph on the 3.9-m Anglo-Australian Telescope, using an iodine absorption cell as a velocity reference, and also with the CORALIE spectrograph on the 1.2-m Leonard Euler Swiss telescope at La Silla. In both sets of data we see a clear excess of power centred at 1.0 mHz, with peak amplitudes of about $0.5\,\mathrm{m\,s^{-1}}$, in agreement with expectations for this star. The time series of velocity measurements from UCLES is shown in Fig. 1.

2. Excess power

We have compared the amount of excess power in the UCLES and CORALIE power spectra, as follows. We first converted both to power density by multiplying the power (in $(\mathrm{m\,s^{-1}})^2$) by the effective timespan of the observations (see Appendix A.1 of Kjeldsen & Bedding, 1995 and Section 5 of Kjeldsen et al., 1999). We calculated this effective timespan by integrating under the (weighted) spectral window. The timespans were 34.9 hr for the UCLES data and 58.1 hr for the CORALIE data. We then calculated the mean power density in the range 700–1300 μHz and subtracted the contribution from noise. The latter was estimated from the mean power density in the frequency range 1900–2200 μHz.

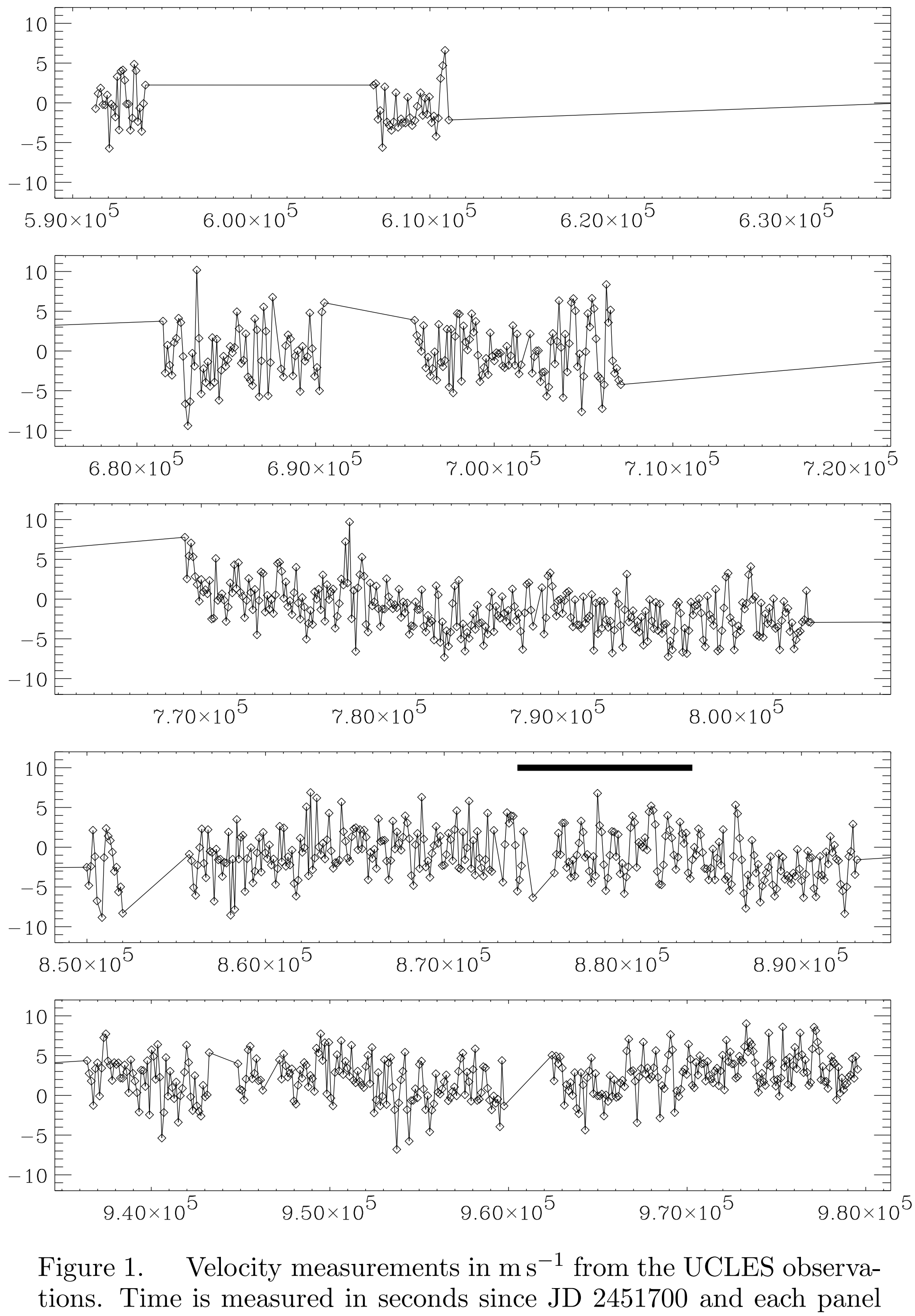

Figure 1. Velocity measurements in $\mathrm{m\,s^{-1}}$ from the UCLES observations. Time is measured in seconds since JD 2451700 and each panel spans 13 hours. The horizontal line on the fourth night is discussed in Sect. 3.

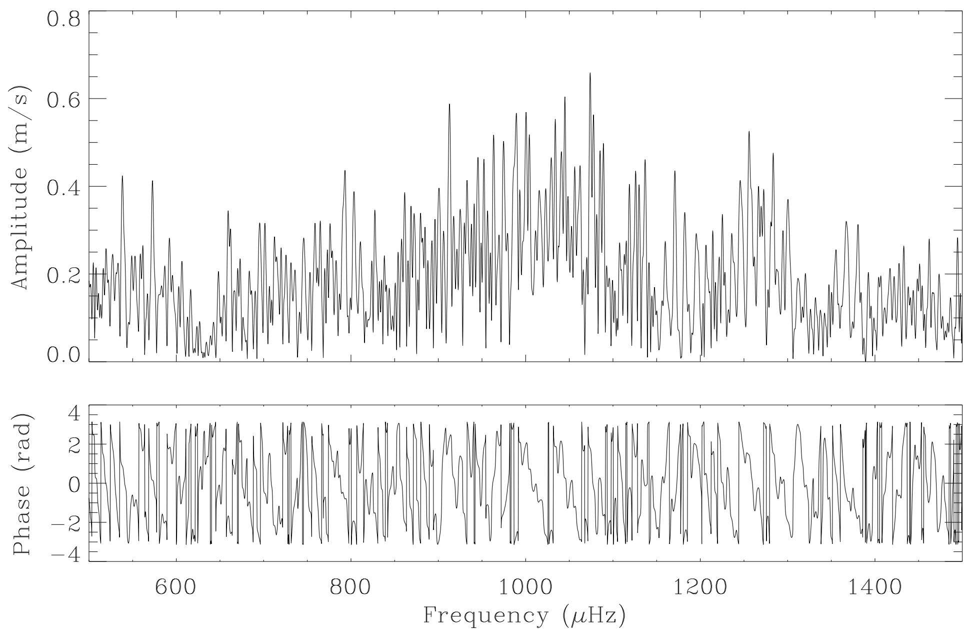

Figure 2. Amplitude and phase of the UCLES velocity measurements of β Hyi.

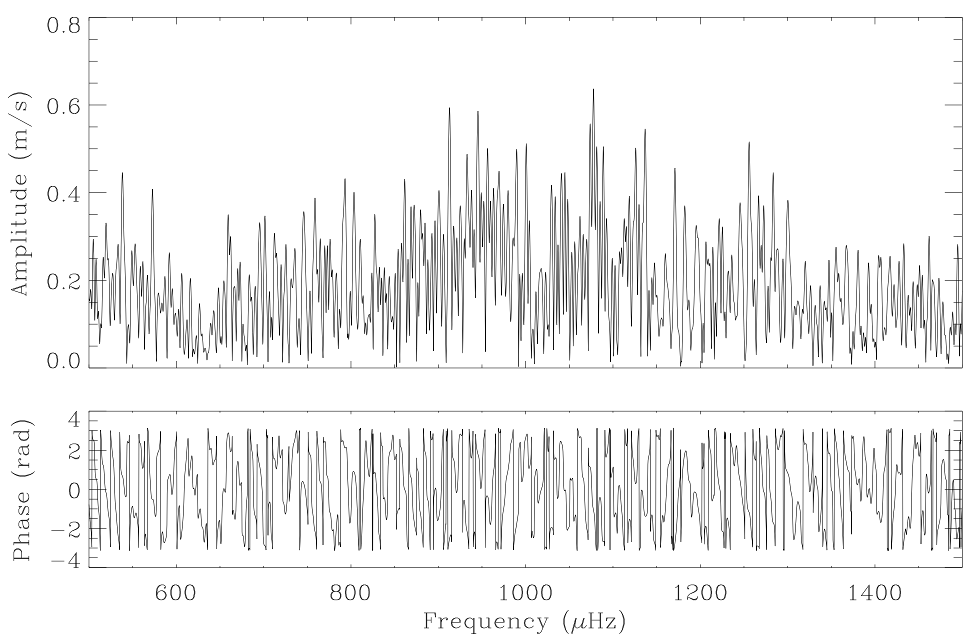

Figure 3. Same as Fig. 2, but with part of the velocity series removed (see text).

The resulting values for the mean excess in power density are 0.0066 and 0.0054 $(\mathrm{m\,s^{-1}})^2/\mu$Hz, respectively for the UCLES and CORALIE observations. The agreement between these values (better than 20%) is good confirmation that both systems were measuring the same power excess.

We also checked the effect of deliberately shifting the relative time stamps of the two series. The amplitudes of the strongest ten or so peaks in the combined power spectrum are maximized when this shift is zero and become significantly reduced when the offset exceeds one minute. This gives strong evidence that highest peaks in the combined power spectrum have a stellar origin.

3. Starquakes ?

An unusual feature of the UCLES power spectrum of (Fig. 2 of Bedding et al., 2001) is a region at the centre of the power excess (1.0 mHz) where the power is everywhere greater than zero. One would expect the power spectrum of a series of discrete long-lived sinusoids to fall to zero between the peaks, not to produce a hump of entirely non-zero power. This hump is more obvious when seen in amplitude (square root of power), as shown here in the upper panel of Fig. 2. There is a region $\sim$80 μHz wide over which the amplitude stays well above zero.

Even more striking is the appearance of the phase (lower panel of Fig. 2.) The phase is coherent over the region in question, which implies that this hump arises from a specific location in the time domain. That location can easily be calculated from the phase, and turns out to correspond to $t_{\mathrm{event}} = 879,000\,\mathrm{s}$ (using the zero point of time as defined in the caption to Fig. 1). We see in Fig. 1 that this part of the velocity series shows clear $\sim$ 17-minute variations, which must be the cause of the non-zero hump. Could this simply be the chance superposition of several modes that happened to be in phase at that time ? That would not produce the non-zero hump, as we have verified with simulations. As far as we can tell, such a hump can only be produced by a short-lived variation that does not continue throughout the whole time series.

We have re-calculated the Fourier spectrum after removing a 10000-s region centred on t_{event} (73 points, indicated by the thick line in Fig. 1). As shown in Fig. 3, this removes the non-zero hump and destroys the phase coherence, confirming that we have identified the correct region of the time series.

Without further evidence, we are left with a puzzle. The UCLES velocities appear to show a short-lived episode of large-amplitude oscillation that we are tempted to describe as a starquake. No similar events are seen in the CORALIE data. If confirmed as a feature of subgiants, this would be bad news for asteroseismology, since they would make it harder to measure accurate mode frequencies.

References

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